

# Topology Based Feature Detection and Tracking

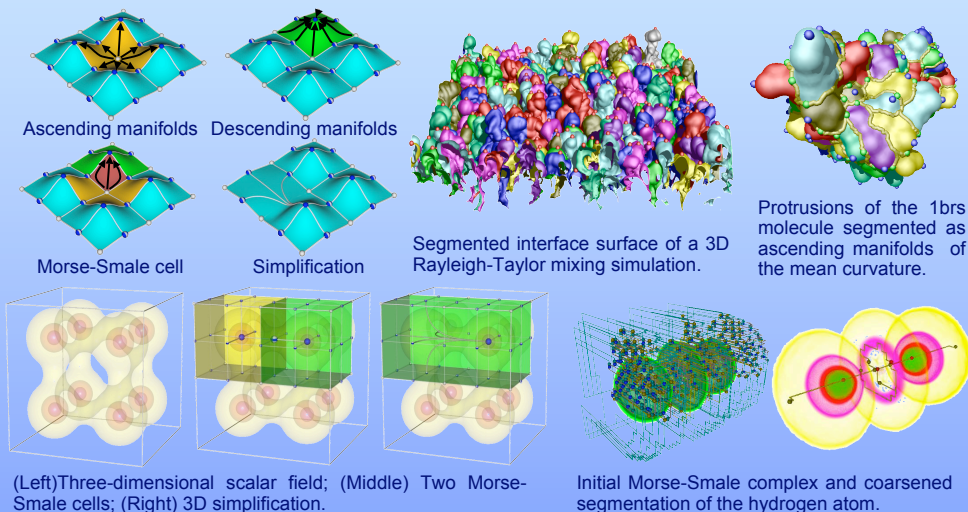
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We present a suit of generic tools to define, analyze, and track features in a variety of applications. Using techniques based on Morse theory we robustly extract features from scalar fields using domain specific functions and filters. The theory guarantees that we find all features and furthermore, organizes them into a stable and flexible multi-scale hierarchy. We use the multi-scale feature definition to remove noise as well to analyze data at different scales.

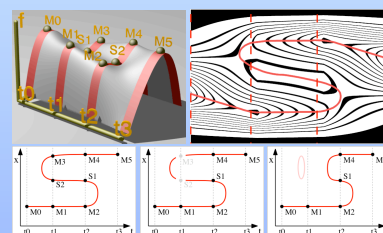
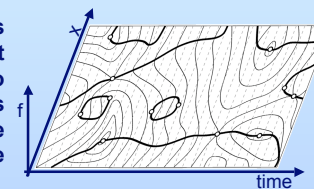
## Feature Detection and Simplification

We define features of scalar functions using their gradient field. Features are represented, for example, as critical points, regions around extrema, or monotone regions. Collectively, these structures form the Morse-Smale complex, a well known domain segmentation

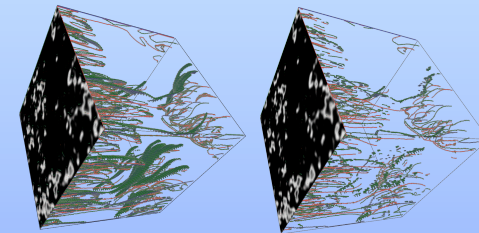


## Feature Tracking

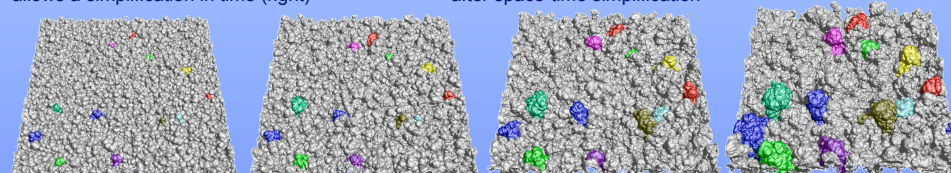
To trace topological features through time we use Jacobi sets which are defined as the set of points where two gradient fields are linearly dependent. Choosing time as one of the two fields allows us to track the movement of all critical points through space and time. Jacobi sets provide the notion of the life-time of a feature and combined with the Morse-Smale complex form a complete space-time feature hierarchy.



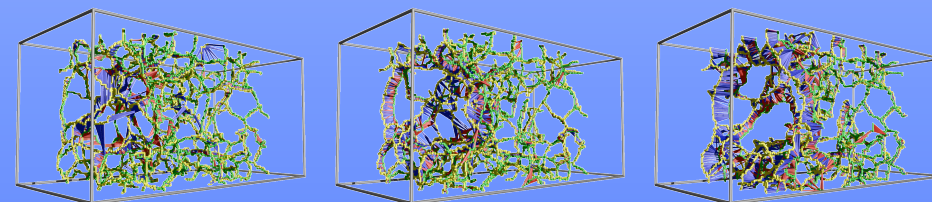
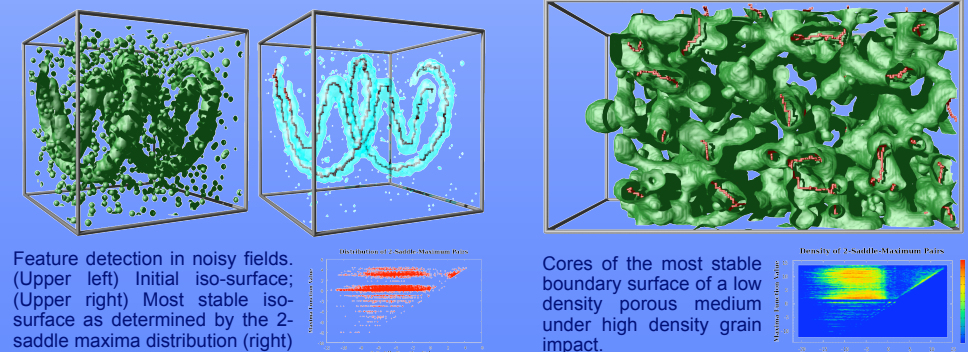
Simplifying a Jacobi set (left) by simplifying first in space (middle) which subsequently allows a simplification in time (right)



Feature tracking in a 2D simulation of an auto-ignition process. (Left) Tracking of all features; (Right) Tracking after space-time simplification



Tracking of bubble structures in the mixing interface of a Rayleigh-Taylor mixing fluid simulation



Extracting and tracing core structures in the simulation of dense grain impacts into low density foam. Each image shows the core structure of two time steps (yellow /green) together with the tracking information (red/blue).